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A joint theoretical and experimental program on the unsteady aerodynamics associated with active vortex flaps employed on delta wings was conducted. Flow visualizations were performed along with quantitative flow field measurements via particle tracking techniques, for a range of dynamic conditions. Additionally, a theoretical point vortex approach was employed to study the vortex dynamics and resultant unsteady loads.

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**FINAL SCIENTIFIC REPORT
FOR
AFOSR CONTRACT NO. AFOSR-85-0318
"STUDIES OF UNSTEADY VORTEX-FLAP AERODYNAMICS"
AUGUST 1, 1985 - JANUARY 31, 1989**

by
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Objective

To determine the effectiveness of leading edge flaps in enhancing the aerodynamic performance of delta wings.

The work consisted of two interacting programmes: one theoretical and the other experimental.

Experimental Program

The experimental program consisted of two major parts: A flow visualisation study linked to quantitative flow field measurements using particle tracking methods.

These publications resulted from this work:

1. "Unsteady Vortex Flows over Delta Wings" in the Proc. of the 2nd AFOSR Workshop on Unsteady & Separated Flows, Colorado Springs, July 1987 (reprint attached).

2. "Performance Analysis of Automated Image Processing & Grid Interpolation Techniques for Fluid Flows", USCAE Rept. 143.

3. "Application of Nueral Networks to 3 Dimensional Particle Tracking in Fluid Flows", USCAE Rept. 146.

The second experimental components consisted of a large number of wind tunnel tests of the appropriate geometries. Here pressure distributions on the upper and lower wing surfaces were measured and intercompared. One major publication resulted: "Generation & Control of Separated Votices over a Delta Wing by Means of Leading Edge Flaps" AIAA paper 89-0997, presented at the AIAA 2nd Shear Flow Conf., (reprint attached).
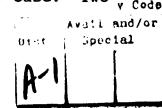
Mr. T. Karagounis will receive a Ph.D. based on this work in May 1990.

Theoretical Program

The theoretical program focused on vortex generation from sharp leading edges and leading-edge flaps, the resulting vortex dynamics and the nonlinear lift. Mainly the point-vortex method implemented with a free-vortex generation mechanism was used in the analyses. The study consisted of two phases: in the earlier phase, we investigated the feasibility of generating and maintaining trap eddies over the wing to enhance the airfoil lift in the steady and unsteady situations. Major findings brought out from this study phase are the lift hysteresis associated with high-lift enhancement in a steady flow, and the appearance of distinct vortex couples associated with the lift cycle in the case of self-induced unsteady fluid motion.

In the second study phase, the point-vortex approach developed for the unsteady two-dimensional problem was applied to a three-dimensional delta wing with vortex flaps via the slender-wing theory. The results on vortex strengths are in qualitative agreement with the concurrent experiment in the steady case. Two

major theoretical findings from the second-phase study are a novel implementation of Sedov's formula for the unsteady nonlift lift expressible in terms of the strengths of shed vortices and their locations, yielding results in excellent agreement with the force obtained by integrating directly with the surface pressure. This led to a clearer definition and physical meaning of the vortex lift. Employing the same formula, we studied the relative merit of the multiple-vortex and the single-vortex (Edwards and Cheng's) model and found that, for a surprisingly wide range of the flap and incidence angles, the simpler, single-vortex model applied to each sharp edge can predict vortex lift as accurately as the multiple system vortex involving three hundred point vortices per edge. The single-vortex model therefore furnishes an excellent theoretical framework to develop a control theory for the vortex lift of slender wing. Except for the last part of the study mentioned, principal results from the theoretical study were documented in the proceedings of three meetings/symposia:

1. Cheng, H.K., Edwards, R.H. & Jia, Z.X. "Simultation Studies of Vortex Dynamics of a Leading-Edge Flap", <u>Studies of Vortex Dominated Flows</u>, ed. M.Y. Hussaini & M.P. Salas, Springer- Verlag, 195-222 (1985).

2. Cheng, H.K. and Jia, Z.X. "Vortex Dominated Aerodynamic Flows as Numerical Experiment with a Point-Vortex Method", <u>Proceedings of Workshop II on Unsteady Separated Flow</u>, ed. M.W. Luttges, M.C. Robison & J.M. Walker, <u>Frank J. Seiler Res. Lab. Report</u> FJSRL-TR-88-0004, 283-228 (1988).

3. Cheng, H.K., Edwards, R.H., Jia, Z.X. & Lee, C.J. "Vortex Dominated Slender-Wing Problems Studied by a Point-Vortex Method", <u>AIAA paper 88-3744</u>. (1988).

A Ph.D. thesis by Z.X. Jia "Simultation of Vortex Dominated Aerodynamic Flows" was completed under current program in May 1988.

<u>Inventions</u>

We have applied for a patent on the basis of the work performed here.

The patent application is presently undergoing review by the appropriate authorities.

<u>Personnel</u>

Co-Principal Investigators	Prof. T. Maxworhty
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